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AIR HYGIENE -- AN AEROSOL PROBLEM

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K. Biss and E. Petras

From the Institute of Aerobiology, Grafschaft/Hochsauerland (Dr K Biss, Director)

Air hygiene generally and in the broadest sense deals with the analysis and synthesis of certain aerosol systems. The objective of its considerations consists of the properties of solid, liquid, and gaseous, animate and inanimate aerosol components and the reciprocal effects between them, as well as the way in which they are influenced by physical and chemical factors.

The distinction between animate and inanimate aerosol components should not be understood here in the sense of a rigid scheme: microorganisms and virus particles are subject, in the atmosphere, to the same physical-chemical influences as the inanimate aerosol components and essentially behave like the latter; they can be converted into inanimate matter and they develop a noteworthy autonomous biological activity only upon entry into more or less strictly specific environmental conditions; they act upon the organisms infected by them through the production of inanimate matter. Conversely, inanimate suspended-substance components can become components of living substance and react with the latter when they meet organisms for a shorter or longer time.

Practical measures of air hygiene are based on thorough analyses of their objectives, specifically:

(a) analyses of aerosol origin and development,
(b) analyses of the behavior of the aerosol components in the atmosphere,
(c) analyses of the normal metabolism output of the exposed organisms and,
(d) analyses of the stress effects triggered.

Furthermore, the way or route of the stress factor until reaction with the organism must be determined as accurately as possible. On the basis of the analysis data obtained, it is then possible to take protective measures:

(a) at the place where the aerosol originates and develops,
(b) in the atmospheric space between the aerosol source and the exposed organism or,
(c) through the formation of resistance in the organism itself.

<u>Inanimate Suspended-Substance Components</u>

Inanimate components constitute, quantitatively speaking, by far the largest portion of the suspended substances [particles in suspension] in our atmosphere. In the Ruhr region alone, about 1.5 million tons of dust, ash, and soot are deposited annually, while simultaneously millions of tons of sulfur dioxide are blown into the atmosphere. It has been estimated that industry's contribution to air pollution in the big cities today amounts to 45%, approximately, while households and small crafts enterprise account for 22% and motor vehicles supply about 33%. High sulfur dioxide concentrations and the presence of carcinogenic substances constitute a constant and immediate threat to the health and life of plants, animals, and man. In addition we have synergistic reactions from various aerosol components, many of which are still quite unknown. In this connection we might mention the formation of "smog," the development of oxidizing substances, acids, and aldehydes through photochemical reactions between the hydrocarbons and nitric oxides coming from the car exhaust aerosols, as well as other possible components. Speaking quite generally, radiation effects and airborne electricity can considerably influence the aggressiveness of an aerosol.

Unfortunately, we are still not putting enough emphasis on the fact that it is not so much the quantity and density of an aerosol that is of interest in any air-hygiene evaluation but rather the qualitative state of that aerosol. Of course, it is necessary to get as accurate a picture of the concentration of certain reactive components in an aerosol, especially since the speed of many reactions that are possible within one aerosol depends extraordinarily on the concentration; some, in themselves possible chemical conversions practically never come about when one of the reaction partners is represented in a density that is too low. On the other hand, however, small traces of some substances — here we might mention the photochemically acting radicals and photosensitisers — can catalyze chemical processes which will alter an aerosol completely from the qualitative viewpoint. The energy conditions within aerosols are quite generally not being given enough consideration today. Furthermore, the surface-active components very considerably influence the character of an aerosol. Apart from the fact that numerous chemical reactions occur on a preferred basis or with specially high speed along the surfaces, we find that the degree of the utilisation of radiation energy can be altered by the presence of surface-active substances. For example, free oxygen absorbs much less sunlight than coal [carbon] particles in absorptively deposited oxygen.

Whether or not liquid systems are present in an aerosol is also of great importance because many chemical reactions occur preferably or only in solutions.

Finally, the size of the suspended particle is of decisive significance in the character of an aerosol. The average duration of time which the smallest, lung-penetrating aerosol components spend in the atmosphere is by far greater than the period of time spent there by the relatively coarse dust and fog particles which often constitute the bulk [main mass] of an aerosol. The processes of self-purification of the atmosphere through sedimentation, wash-out, photochemical reactions, sorption forces along the earth's surface, etc, are the subjects of detailed investigations.

With respect to the air-hygiene evaluation of any toxically acting or radioactive aerosols we therefore find the following applicable, in the sense of what we have said so far: it is not so much the absolute measure of air pollution at any particular point of time that is of importance, but rather the sustained effect caused by this air pollution.

For the time being, we do not know enough to develop an absolutely reliable air surveillance system based only on physical and chemical measurement methods; therefore, one of the currently most important tasks is the creation of a system of biological control of aerosol emissions. This problem is difficult to solve inasmuch as plants and many species of animals likewise generally react in a manner that differs considerably from the reaction in man and that this reaction in most cases is by far more sensitive in response to aerosol influence. This is why Soviet air-hygiene experts used the human reactions to aerosol stimuli -- for instance, fluctuations in the light sensitivity of the eye -- in setting up index values for the maximum permissible content of the atmosphere in terms of certain suspended substances. These values (Table 1) are far below those customary throughout the world in industrial regions and they are mandatory only for new installations in the Soviet Union likewise.

Animate Suspended-Substance Components

Animate suspended-substance components can be conceived as chemical agents which, under certain conditions, have the capability of multiplying independently. This kind of aerosol develops in nature primarily as a result of the effects of air currents upon the surface of the earth and the oceans. Particularly high local concentrations of animate suspended-substance components originate through the separation [of waste] by man and animal. For instance, the germ content of the air is particularly high in all kinds of gatherings, such as in motion picture theaters, schools, warehouses, hospitals, and apartment houses.

TABLE 1

STANDARD VALUES ESTABLISHED BY SOVIET CLEAN-AIR COMMITTEE

Stoff (a)	Maximale einmalige Konzentration (b) in mg/m³	Mittlere 24stündige Konzentration (c) in mg/m³
Schwefeldioxyd (1)	0,50	0,15
Chlor (2)	0,10	0,03
Schwefelwasserstoff (3)	0,03	0,01
Schwefelkohlenstoff (4)	0,50	0,15
Kohlenoxyd (5)	6,0	2,0
Stickoxyde (6)	0,50	0,15
Nichtgiftiger Staub (7)	0,50	0,15
Ruß (8)	0,15	0,05
Phosphorsäureanhydrid (9)	0,15	0,05
Mangan und seine Verbindungen (10)	0,03	0,01
Verbindungen des Fluors (11)	0,03	0,01
Schwefelsäure (12)	0,30	0,10
Phenol (13)	0,30	0,10
Arsen (anorganische Verbindungen außer Arsenwasserstoff) (14)	—	0,003
Blei und seine Verbindungen außer Bleitetraäthyl (15)	—	0,0007
Metallisches Quecksilber (16)	—	0,0003

Key:
- a. Substance
- b. Maximum one-time concentration in mg/m³
- c. Average 24-hour concentration in mg/m³
- 1. Sulfur dioxide
- 2. Chlorine
- 3. Hydrogen sulfide
- 4. Carbon disulfide
- 5. Carbon monoxide
- 6. Nitric oxide
- 7. Nontoxic dust
- 8. Soot
- 9. Phosphoric anhydride
- 10. Manganese and its compounds
- 11. Compounds of fluorine
- 12. Sulfuric acid
- 13. Phenol
- 14. Arsenic (inorganic compounds with the exception of arsenic hydride)
- 15. Lead and its compounds, with the exception of lead tetraethyl
- 16. Metallic mercury

The dissemination of animate aerosol components can cover hundreds of kilometers; a typical example here is the spread of grain rust whose spores very often are blown all over Europe from their source. Migration distances of up to 3,000 km have been determined for microorganism cells. And they also reach very high up: living microorganisms have been isolated from elevations of more than 20,000 meters. Of course, the germ count in the upper layers of the atmosphere decreases not only absolutely but also relatively. For instance, Proctor (1934) reports that he found an average of one microorganism for every 108 dust particles in the lower layers of the atmosphere whereas he found only one microorganism for every 118 dust particles at altitudes of more than 3,000 meters; this corresponds to a kill rate of about 8%. Among the microorganisms frequently found in the atmosphere we have above all the spore-forming and other types of bacteria, such as achromobacteraceae, micrococcaceae, and sarcines, as well as the spores of actinomyces and low fungi; yeasts were also observed relatively frequently. Microorganisms that are pathogenic to man have not been found even at moderate altitudes; on the other hand, spores of fungi that are pathogenic with respect to plants were found to be widespread. Because of their speed of multiplication, which is not achieved anywhere in the remaining sphere of organisms — one single bacterium cell, under favorable conditions of life, can produce sometimes more than 1 million cells of descendants within 10 hours — we find that even very small quantities of microorganisms or virus particles can cause economic damage or epidemics of the very greatest proportions, events that, moreover, are difficult to predict and anticipate. On the other hand, it is possible to "mark" aerosols by adding relatively few microorganisms and to study the fate of an aerosol with their help.

The viability of microorganism particles or virus particles suspended in the atmosphere may vary greatly in terms of duration. No maximum limit is known here. The most important factors influencing this duration are the [relative] air humidity, the temperature, the radiation dose, chemical additions, protective colloids, and other surface-active substances, etc. Assuming that the environmental conditions are the same, the mortality curve generally follows a logarithmic function, although the picture is frequently complicated because of the appearance of particularly resistant forms. In most cases the germs are killed by the denaturing of proteins by the breakup of H-H and S-S bridges, etc. This process can be speeded up with the help of high temperatures or chemical additions or also by means of radiation — in that case we speak of sterilization or disinfection. Conversely, the lifetime of germ [virus] particles can be prolonged by providing these particles with additions which counteract the denaturing process.

Protective measures against toxically acting air viruses [germs] first of all are based on the isolation or elimination of sources of infection and then also on efforts to keep the air clean through chemical disinfection, radiation, ventilation, direct airing, etc.

One extraordinarily effective means for protection against infectious air germs finally is the immunization of man and animals and the breeding of resistant races of animals and varieties of plants. Immunization through

aerosols will probably assume considerable significance here in the future because there are many possibilities for rational mass immunization when we use weakened [diluted, reduced] viruses, that is to say, virus particles with low toxicity but with undiminished antigenic effectiveness. For instance, aerosols consisting of diluted virus material have already been used for the immunization of entire chicken farms against Newcastle disease, infectious bronchitis, and fowl diphtheria [fowl pox] (see Bibliography, Fritzsche, 1961). In this connection it was found that in case of aerogenic immunization with Newcastle disease live vaccine the hemaglutination titer rose more than twice as high as when the vaccine was added to drinking water. When chicks were inoculated against Newcastle disease at the age of 5 days and then at the age of 4 weeks, 94% of them became immune in case of drinking water vaccination while 100% became immune following aerogenic vaccination. Similar experiments were conducted by Gorham and associates (1954) in an effort to protect ferret and mink breeding farms against distemper; these authors managed to make ferrets completely immune by means of aerosolized egg-adapted distemper virus within 5 days and to achieve similar results in the case of mink.

Aerosolized live vaccine likewise created many possibilities for the protection of man here. In the Soviet Union, for instance, investigations were conducted in connection with the aerogenic immunization against pest, tularemia, anthrax, and brucellosis; in the United States, experiments along these lines were conducted with tularemia and tuberculosis. Alexandrov et al (1958-1959) found that sheep infected with anthrax revealed a death rate of only 3.3% after prior aerogenic vaccination -- as against 5% in the case of subcutaneous and 16.3% in the case of percutaneous vaccination, whereas the death rate among the noninoculated controls was 73.3%. These same authors also conducted experiments for the aerogenic immunization of man against anthrax. According to their data, it was possible to vaccinate 300 people in a room the size of 40 cu m, within 1 hour; each subject was exposed for 5 minutes. Here the minimum quantity of viable vaccine cells to be inhaled per person was 100,000; in some cases, 10^{12} and more cells were inhaled. Eigelsbach et al (1960-1961, 1962) observed an increased degree of immunity compared to subcutaneous innoculation, in the case of guinea pig and monkey experiments, when aerogenic tularemia vaccination was administered. Middlebrook (1961) arrived at the same result in the BCG vaccination of guinea pigs: aerogenic treatment with 20 viable BCG units proved to be more effective than subcutaneous injections of 200 units and 10 viable aerosolized units had the same effect as 10^6 intracutaneously injected viable units. Immunity could still be established after 2 years. According to Rosenthal (1961), human beings required on 10 times the vaccine dose required for the guinea pig experiment, in case of aerogenic BCG immunization. Elsewhere, investigators are currently trying to develop a spray method for the fa[illegible] immunization of large population groups against grippe virus infections.

The problems we have mentioned here can only constitute examples for the vast problem complex of air-hygiene which keeps growing, day after day. Along with the increase in the number of problems there is also an increase in the number of ways to solve these problems. Our world today has become very small and it is relatively easy to get a complete picture in many

respects. This means that we are forced -- and also increasingly in a better position -- to view the individual problems of air-hygiene in their interconnections and to solve them -- within the over-all framework of geohygiene.

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